GREENVILLE BENCH CASE STUDY ANALYSIS

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Abstract

This paper presents the use of two models to aid managers in identifying and prioritizing areas for landscape fuel treatments. Treatment areas were selected by fire managers from the Bureau of Land Management based on the threat of fire to communities and the need for watershed, range, and wildlife improvement. FlamMap was used to calculate fireline intensity and crown fire activity. The Minimum Travel Time technique was used to reveal the most influential travel paths of fire spread. Output from both models reveal potential areas of concern and aid managers in the prioritization of these areas for landscape fuel treatments.

Introduction

Fuel modifications are receiving renewed interest as protection strategies, particularly in wildland-urban areas (Agee and others 2000). This is a result of costly fire seasons like 2000 and 2002, new national directives with increased funding (USDA Forest Service and USDI 2000), a recognition of a change in fuel composition, structure, and loading, and fire manager's desire, yet limited ability, to control large fires. The primary purpose of a fuel treatment is to change the behavior of a fire entering a fuel-altered zone, thus lessening the impact of that fire to an area of concern. This is best achieved by fragmenting the fuel complex and repeatedly disrupting or locally blocking fire growth, thus increasing the likelihood that suppression will be effective or weather conditions will change (Finney 2000).

Recent research suggests that landscape-scale fuel modifications, such as prescribed fire, are the most effective way to modify the behavior and growth of large fires (Finney 2001), but managers have lacked the tools and information necessary to identify and prioritize treatment areas at a landscape level. This paper presents the use of two models to aid in identifying and prioritizing areas for landscape fuel treatments: FlamMap (Finney, in preparation) and the Minimum Travel Time (MTT) (Finney 2002).

Analysis Area

Greenville Bench is located approximately 10 miles southwest of Beaver, Utah and is south and east of the communities of Greenville, Adamsville, and Minersville (Figure 1). The project area (approx. 40,000 acres; 5,600 to 7,600 ft) is on Bureau of Land Management (BLM) administered land and bounded by private ownership to the north (Greenville Bench Road and State Road 21), Interstate 15 (I-15) to the east, Rocky Ford Hollow to the west (BLM), and a ridgeline to the south (Bald Hills; BLM). Several sections of State administered land is distributed throughout the area. The Greenville Bench and associated uplands are southeast of Minersville Reservoir, constituting the southwestern quarter of the Beaver River Watershed.

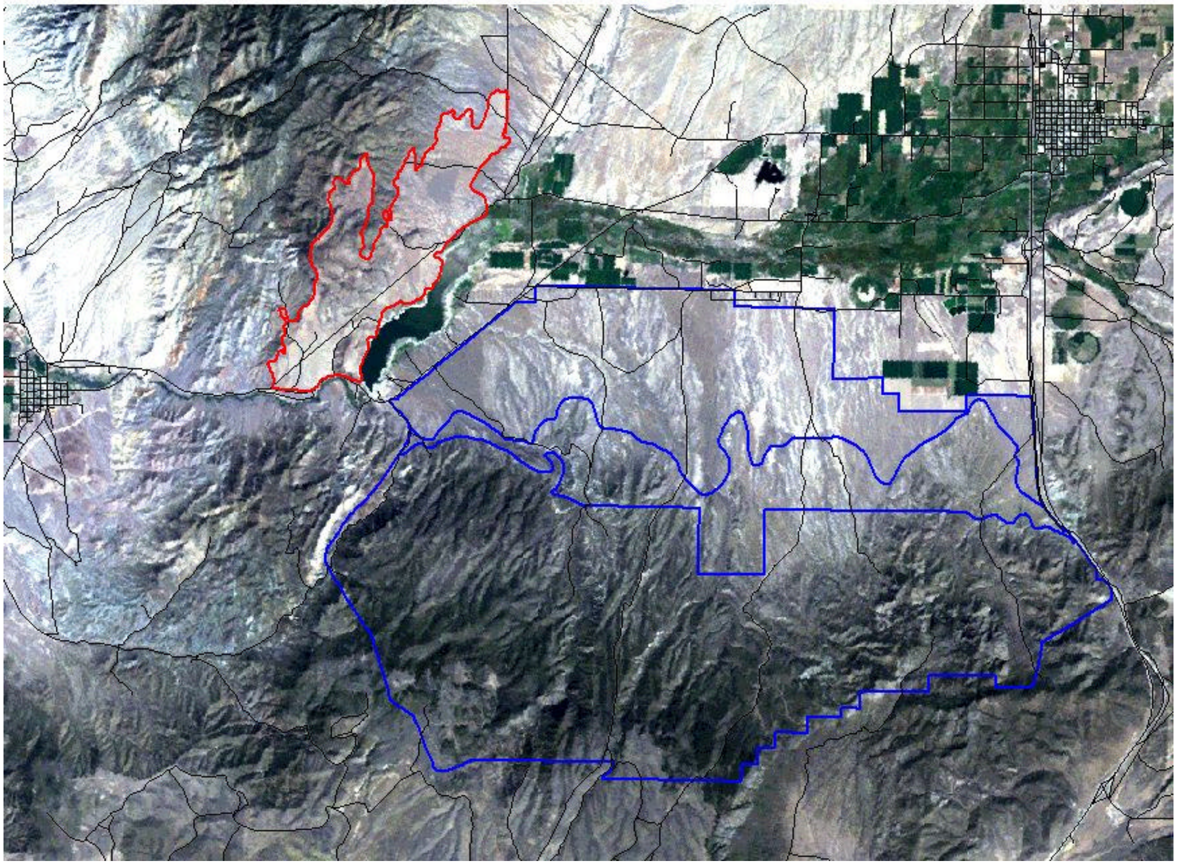

Figure 1. Vicinity map of the Greenville Bench project area. The blue polygon is the project boundary divided primarily by sagebrush to the north (up) and pinyon-juniper to the south. The Minersville Fire of 1998 (4,060 acres) is in red and roads are in black, with Beaver, UT in the northeast corner and Minersville to the west. The base map is a LANDSAT 5 Thematic Mapper image, bands 3, 2, and 1.

Located on an alluvial fan, the relatively flat bench transitions to steep, north facing slopes. The dominant vegetation communities on the lower bench are sage brush (*Artemisia tridentata*) (1-3 ft), interspersed in a lesser degree with crested wheatgrass (*Agropyron cristatum*), bluebunch wheatgrass (*Elymus spicatus*), junegrass (*Koeleria macrantha*) (1-2 ft), transitioning on the upper slopes to dense stands of Utah juniper (*Juniperus osteosperma*) and pinyon pine (*Pinus edulis*) (10-35 ft), with some oak (*Quercus turbinella*; *Quercus gambelii*) in the draws (4-15 ft).

Summer cold fronts contribute to strong winds that are channeled through the State Road 21 corridor and the surrounding area and onto the lower Greenville Bench. The effect of these winds on fire growth is evidenced by the Minersville Fire of 1998 (4,060 acres) (Figure 1). The area has a history of fires attributed to recreational use, I-15 through traffic, and lightning on the Mineral Mountains to the northwest (9,600 ft) and the Black Mountains to the southwest (8,000 ft).

Due to decades of fire suppression and previous grazing practices, pinyon-juniper woodlands have increased in range and density and currently occupy areas previously dominated by sagebrush and perennial grasses. Furthermore, remnant shrublands now contain mostly homogenous stands of mature sagebrush, with declining native perennial forbs and grasses. Higher elevation areas where dense pinyon-juniper exists have little understory, the presence of which is important to wildlife and ecosystem stability. The sagebrush corridors that once connected the Bald Hills with Greenville Bench, and facilitated the movement and dispersal of sagebrush obligate species (e.g., sage grouse), have been eliminated due to the pinyon-juniper encroachment (USDI 2003).

> The following actions have been identified by resource and fire management professionals as necessary on the Greenville Bench area: 1) establishing fuel breaks along selected roads, property lines, and topographic features on the lower sagebrush bench creating a situation where wildfires can be better managed by reducing the rate of spread and giving fire fighters additional response time to suppress fires; 2) decreasing the hazardous fuel loads on the mid and upper slopes in the pinyon-juniper woodland, thereby protecting against the threat of catastrophic wildfires leaving the woodlands and impacting neighboring private lands and I-15; 3) re-establishing sagebrush corridors between the Bald Hills and the Greenville Bench allowing for better dispersal and movement of wildlife species; 4) decreasing the amount of pinyon-juniper encroachment into areas historically dominated by big sagebrush; 5) increasing plant diversity within the treatment areas by establishing a mix of native and non-native shrubs, forbs, and grasses that would also facilitate a decrease in surface soil erosion as a result of precipitation and wind. (USDI 2003)

Methods

Specific information about the project area, such as objectives of the proposed treatment (e.g., wildfire control, wildlife enhancement), type of treatment (e.g., prescribed fire), and supporting Geographic Information System (GIS) data were obtained from the BLM. A 32-year fire ignition layer for the BLM was used to derive a fire density grid, using ArcView/Spatial Analyst (ESRI 2000) (Figure 2).

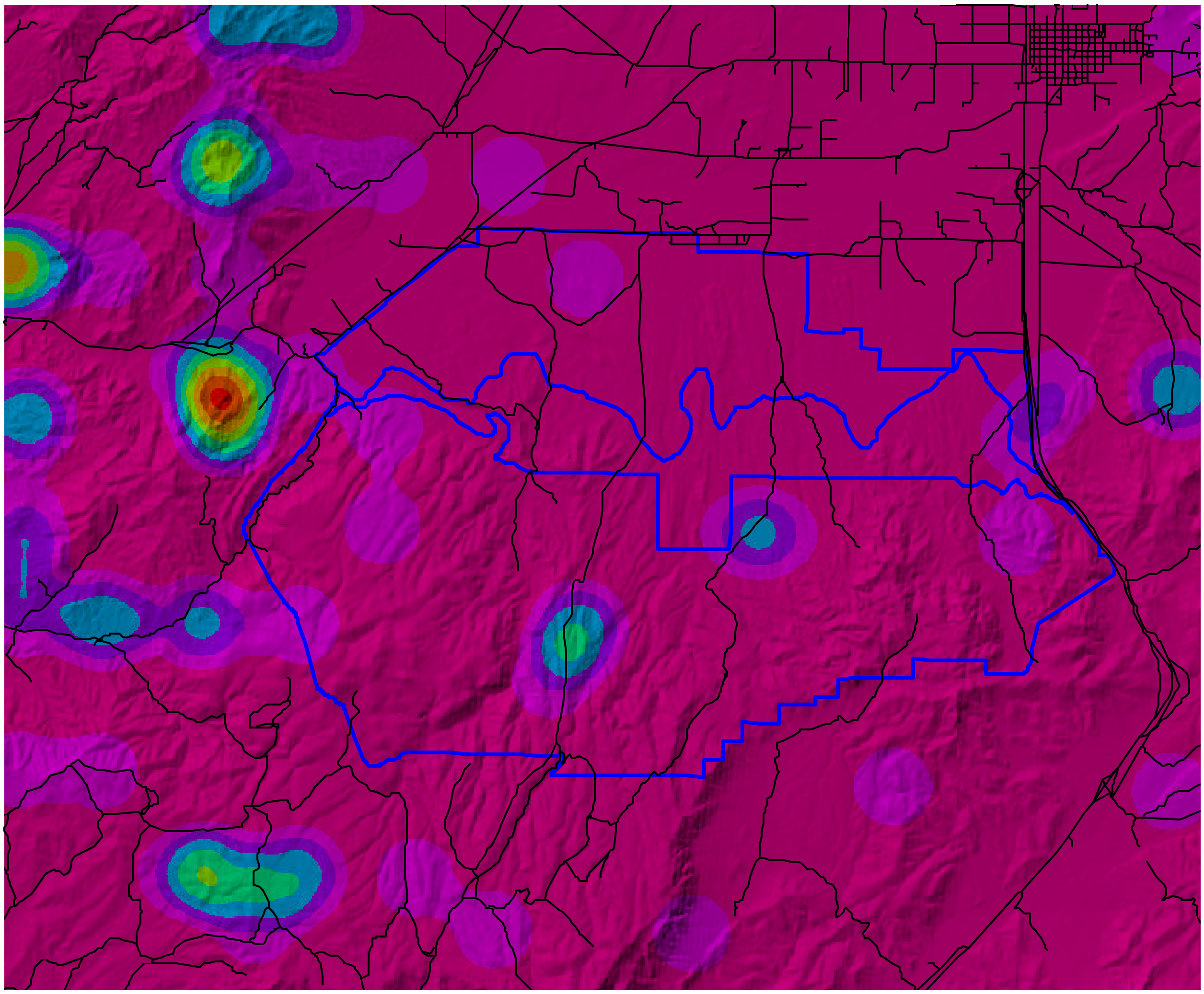

Figure 2. Thirty-two year (1970-2001) fire density grid of the Greenville Bench area. The blue polygon is the project area divided primarily by sagebrush to the north (up) and pinyon-juniper to the south; roads are in black. Fire density is recorded by number of fires per square mile and range from 0 fires (lavender), 1 fire (purple), 2 fires (green), 3 fires (blue), and 4 fires (red).

Locations of the nearest Remote Automated Weather Stations (RAWS) were identified and reporting history and site characteristics were analyzed to determine the most adequate station for the project area. Horse Hollow, approx. 20 miles north of Beaver, UT, with a 13-yr history, was selected and its information downloaded from NIFMID/KCFAST (USDA Forest Service 1993; USDA Forest Service 1996) fire occurrence information retrieval site and imported into Fire Family Plus (Bradshaw and McCormick 2000).

Vegetation and Fuel Models

Spatial vegetation data for the project area was extracted from a larger 15 million acre study area (Long and others, in preparation). A supervised classification of LANDSAT

Thematic Mapper data—path 33 and rows 37 and 38—was used with ERDAS IMAGINE software (ERDAS 1999), incorporating polygons created by the IPW image processing program (Frew 1990). A maximum likelihood algorithm in ERDAS was used to classify the imagery based on a statistical representation of spectral signatures for each vegetation class created from field sampling. Ancillary layers, including land use and land cover, were used in combination with the classified imagery to assign polygons to one of 65 final vegetation classes.

The vegetation classes were cross-walked to 44 fuel models (including barren and water), 35 of which were "customized" models (i.e., the standardized model parameters (Anderson 1982) were altered to reflect a condition not adequately represented by the fire behavior models) and two, were custom models (i.e., 14: sparse grass-forb; 35: sparse shrub). Canopy cover, stand height, crown-base height, and crown bulk density were developed based on field data, anecdotal observations, and previously published work. Moderate and severe custom fuel files (*.FMD) were built to reflect the differences in fire behavior between moderate and high/severe conditions.

Terrain, fuel model, and canopy information was used to construct two modeling landscapes: pre-treatment and post-treatment. Lower bench sage-dominated areas were assigned either a fire behavior model (2, 6) or a customized model (e.g., 2-, 5+, 6-, etc; where the "-" or "+" represents a 20% change in the loading and depth). Stands of pinyon-juniper and oak were assigned a standardized fuel model (4, 6) or a customized model (4-, 6-, 6--), *each with varying canopy characteristics*.

<u>Fire Family Plus</u>

Fire Family Plus is a fire climatology and occurrence program that combines and replaces the PCFIRDAT (Cohen and others 1994; Main and others 1990), PCSEASON (Cohen and others 1994; Main and others 1990), FIRES (Andrews and Bradshaw 1997), and CLIMATOLOGY (Bradshaw and Fischer 1984) programs into a single package with a graphical user interface. It allows the user to summarize and analyzing weather observations and compute fire danger indexes based on the National Fire Danger Rating System (NFDRS) (Bradshaw and others 1983; Burgan 1988).

Fuel moistures (i.e., 1-, 10-, 100-hr, live herbaceous, live woody) were obtained from a Fire Family *Percentile Weather Report*. Calculated fuel moistures were compared with local field sampling to validate and adjust the values. Wind speed, temperature, and relative humidity were obtained from a S*easonal Severity Report*; wind direction was obtained from a *Wind Speed vs. Direction Report*. Wind speeds were modified to account for persistent gusts (NOAA 2003).

All weather and fuel moisture information was recorded at the 90th percentile (Table 1). In other words, weather occurring during the reporting period (June 1-September 30) 10% of the time is represented by the 90th percentile. This percentile was used because suppression forces are virtually ineffective when weather and wind conditions are between the 88th and 95th percentile. All climatological and fuel variables were then used to develop the required weather and wind files/inputs for FlamMap and the MTT.

Table 1. Weather and fuel moisture information for the 90th percentile from the Horse Hollow RAWS and reported by Fire Family Plus and modified as noted (*/**).

	90th
1-hr (%)	3
10-hr (%)	5
100-hr (%)	6
Live Herbacious (%)*	60
Live Woody (%)*	90
Foliar Moisture Content (%)	85
20-ft Windspeed (mph)**	20
Wind Direction (°)	235

*Adjusted from the *Seasonal Severity Report* based on local field sampling.

**Adjusted from the *Seasonal Severity Report* to account for wind gusts (NOAA 2003).

FlamMap

FlamMap is a spatial fire behavior mapping and analysis program, which requires a FARSITE (Finney 1998) landscape file (*.LCP), as well as terrain, fuel, and weather data. However, unlike FARSITE, FlamMap assumes that *every* pixel on the raster landscape burns and makes fire behavior calculations (e.g., fireline intensity, flame length) for each location (i.e., cell), *independent* of one another. That is, there is no predictor of fire movement across the landscape and weather and wind information can be held constant. By so doing, FlamMap output lends itself well to landscape comparisons (e.g., pre- and post-treatment effectiveness) and for identifying hazardous fuel and topographic combinations, thus aiding in prioritization and assessments.

Minimum Travel Time

Fire travel times across a two-dimensional landscape were calculated by overlaying a rectangular lattice on a spatial data set consisting of terrain, fuels, fuel moisture, and wind. The MTT was then obtained by searching for the fastest path of travel along straight-line transects connecting the nodes (cell corners) of the lattice (Finney 2002). These MTT paths were then interpolated to reveal the position of the fire perimeter at an instant in time. Based on output from the MTT algorithm, the amount of land area burned after the fire exists each node is calculated and nodes exhibiting the greatest “fire influence” are revealed.

Fire perimeters and behavioral characteristics (e.g., spread rate, fireline intensity) from the MTT closely resemble products from perimeter expansion models, such as FARSITE, but because MTT methods are more readily parallelized, processing time is significantly decreased (Finney 2002).

Model Checking and Execution

To produce fire growth and behavior output consistent with observations, model checking, modifications, and comparisons were done using fire models, such as FARSITE and Behave Plus (Andrews and Bevins, in preparation), case studies, other published work, and anecdotal observations. Ninetieth percentile weather and fuel conditions were imputed into FlamMap and the MTT. A wind direction of 235° was used in Flammap and the MTT based primarily on the historical weather analysis, but confirmed by spread directions of previous large fires. A line ignition along the western extent initiated fire spread into the study area.

Results

Figure 3 and 4 displays FlamMap output for the for 90th percentile weather and fuel condition. Fireline intensity (Figure 3) is expressed in BTU/(ft·sec) and concentrated to the lower values. Crown fire activity (Figure 4) is expressed categorically as either areas of no fire (i.e., barren, water), surface fire, passive crown fire, or active crown fire.

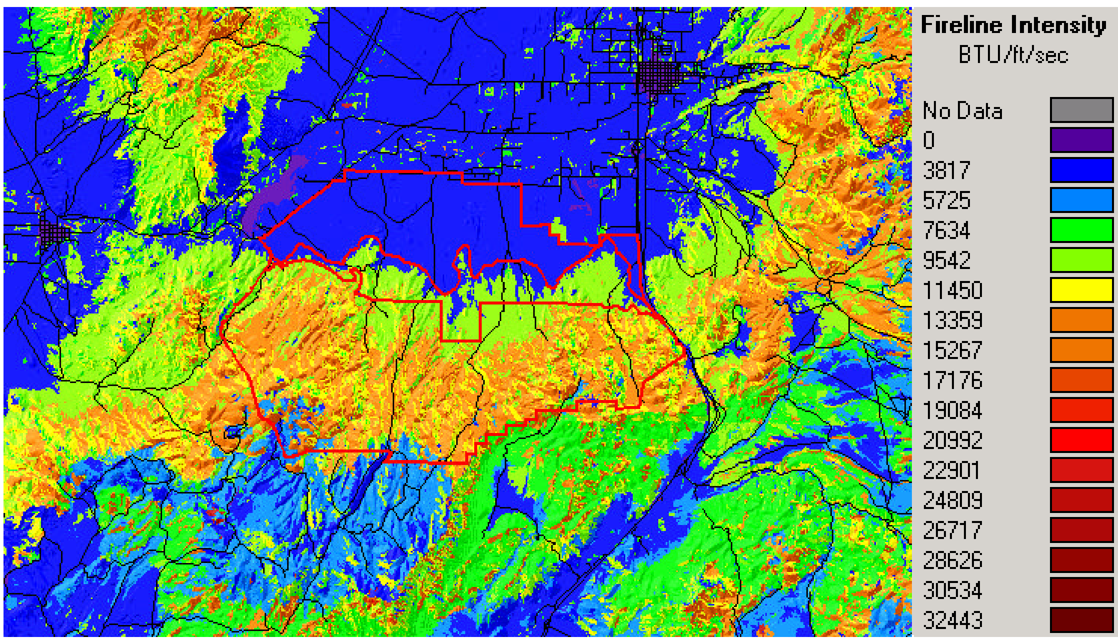

Figure 3. FlamMap fireline intensity map for the 90th percentile weather condition. The red polygon is the project area divided primarily by sagebrush to the north (up) and pinyon-juniper to the south; roads are in black, with Beaver, UT in the northeast corner.

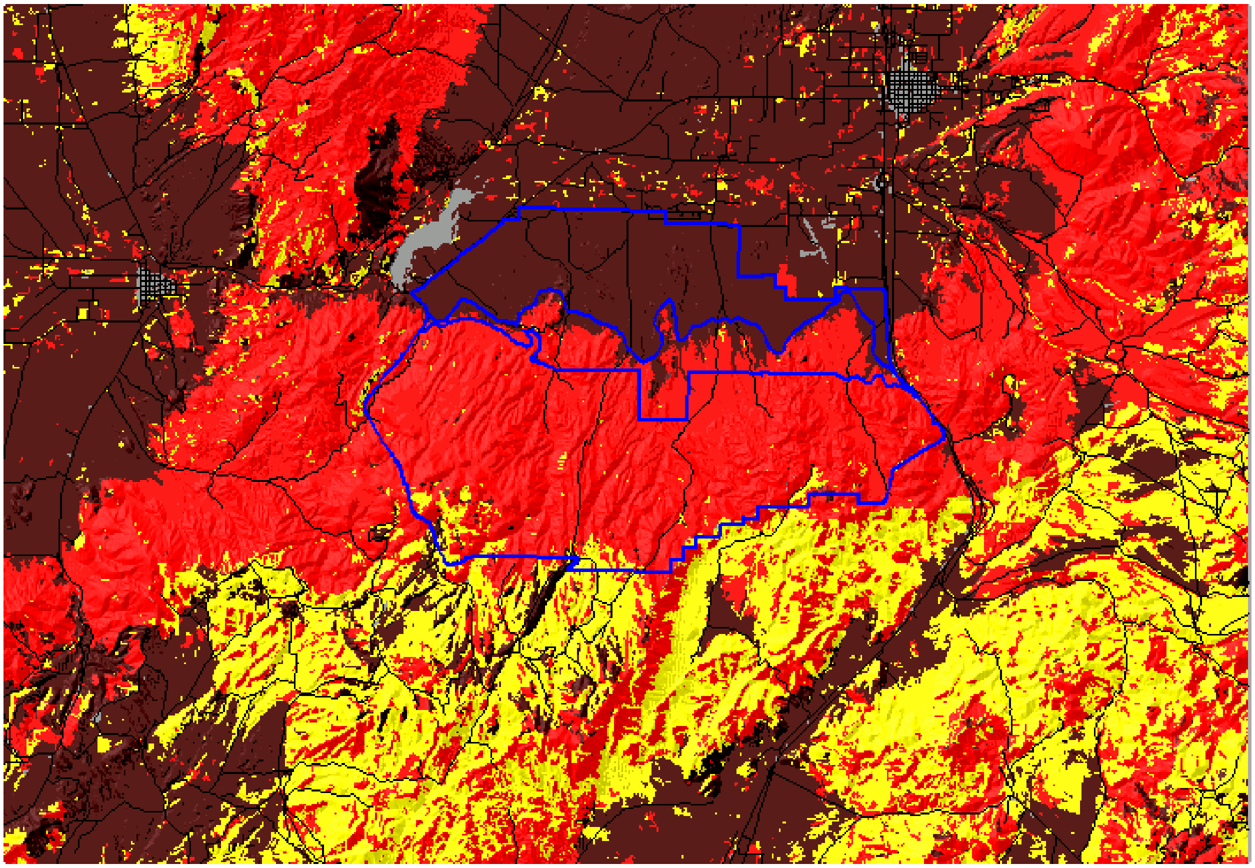

Figure 4. Crown fire activity map for the 90th percentile weather condition. The blue polygon is the project area divided primarily by sagebrush to the north (up) and pinyon-juniper to the south; roads are in black, with Beaver, UT in the northeast corner. Crown fire activity is recorded by no fire areas (gray), surface fire (dark red), passive crown fire (yellow), and active crown fire (red).

Figure 5 displays fire influence pathways derived from the MTT technique. These paths indicate the corridors where the greatest amount of land area was burned. The various colors are a measure of land area burned, where the red and orange pathways went on to burn the most acreage, followed by yellow, then green.

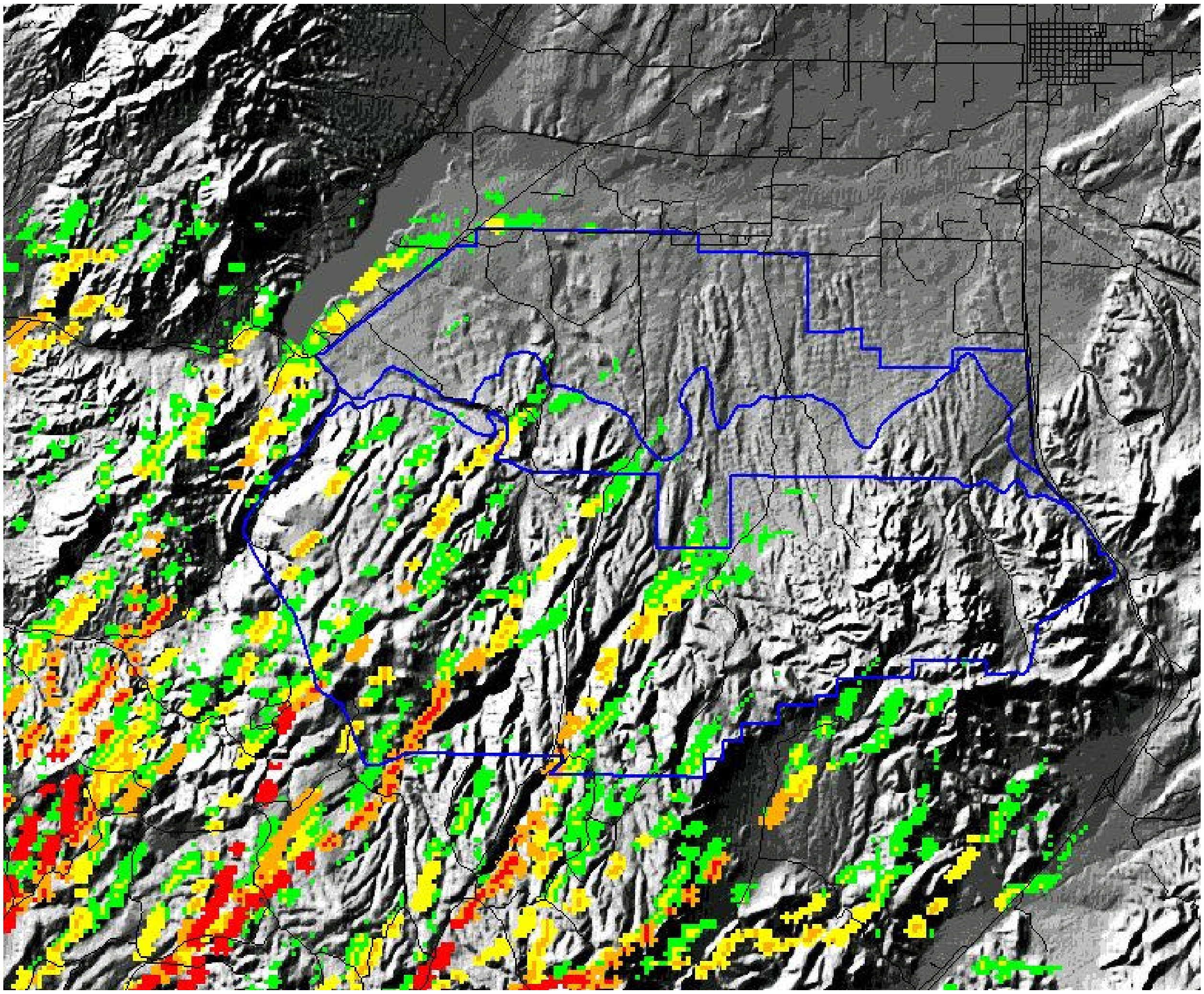

Figure 5. Pathways of "greatest influence" derived from the MTT technique for the 90th percentile weather condition. The various colors are a measure of land area burned, where the red and orange pathways went on to burn the most acreage, followed by yellow, then green. The Greenville Bench project area is the blue polygon with Beaver, UT in the northeast corner. Roads are colored black, and overlaid with a 30-meter shaded relief map.

Discussion

<u>Modeling Assumptions and Limitations</u>

There are several assumptions and limitations to the methodology presented in this paper. FlamMap and the MTT method, as well as the models utilized by these modeling systems (e.g., surface fire spread), operate under a broad range of assumptions and have specific limitations. Spatial data has resolution and accuracy limits inherit to mapping of heterogeneous surface and canopy fuels and terrain. Vegetation cross-walked to fuel model and fuel model assignments of treated landscapes are occasionally problematic and model output is largely a reflection of these "conversions." Moreover, the MTT algorithm is still under development and this paper constitutes it first applied use; thus, it is important that users understand model constraints, and more importantly utilize models and output within accepted bounds.

Model Output and Discussion

Products form FlamMap and the MTT technique can assist managers in identifying areas of concern and aid in the prioritization of these locations for fuel treatment. Although these output grids are in themselves limiting, collectively they provide useful information for assessing wildland fire danger.

Fireline Intensity

The fireline intensity grid can be used to identify areas of potential concern. Higher intensity areas generally are more resistant to control, exhibit high flame lengths, spotting, and mortality.

Crown Fire Activity

The crown fire map can be used to reveal areas prone to active crown fire. Such areas are generally very difficult to control, prolific spotters, and exhibit high rates of spread. Thus, targeting areas such as these for landscape fuel modifications could prove beneficial.

MTT

Unlike fireline intensity and crown fire activity (i.e., fire behavior predictors of the physical setting), the MTT algorithm identifies potential areas of concern based on fire growth. There are two principal uses of this information: mitigating large fire growth and behavior and the protection of human and ecological values. To aid in reducing large fire growth, pathways of primary influence (i.e., the red and orange, or those areas that went on to burn the most acreage) can be targeted for landscape fuel modifications. By applying these treatments heuristically—to multiple areas, in varying sizes and shapes—modifications in large fire growth and behavior will be realized.

To protect areas of concern such as wildland-urban areas, threatened and endangered species habitat, cultural resources, etc., secondary corridors should be overlaid with protection areas to identify areas of hazard (i.e., a physical situation with a potential for loss (Allen 1992). Finer-scale treatments can then be designed to mitigate the risk to these protection areas.

Conclusion

Managers have a growing need to identify and prioritize landscapes for fuel treatment, however this need has outpaced the development of spatial models to accomplish the task. FlamMap provides managers with estimations for fireline intensity and crown fire activity. Use of the MTT identifies likely spread routes and high influence pathways. These data are beneficial in identifying and prioritizing areas for landscape fuel treatments. However, to sufficiently alter fire growth and behavior an interactive approach, where managers would run the MTT, input fuel treatments, and rerun the algorithm—possible several times—would reveal an improved treatment design. It is anticipated that future versions of FlamMap will incorporate the MTT technique and an optimization model to accomplish this task.

References

Agee, J. K.; Bahro, B.; Finney, M. A.; Omi, P. N.; Sapsis, D. B.; Skinner, C. N.; van Wagtendonk, J. W.; Weatherspoon, C. P. 2000. **The use of shaded fuelbreaks in landscape fire management**. Forest Ecology and Management. 127: 55-66.

Allen, F.R. 1992. **The management of risk to society from potential accidents**. Essex, UK.

Anderson, H. E. 1982. **Aids to determining fuel models for estimating fire behavior**. Gen. Tech. Rep. INT-122. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 22 p.

Andrews, Patricia L.; Bradshaw, Larry S. 1997. **FIRES: Fire Information Retrieval and Evaluation System - a program for fire danger rating analysis**. Gen. Tech. Rep. INT-GTR-367. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 64 p.

Andrews, Patricia L.; Bevins, Collin D. [In preparation]. **BehavePlus fire modeling system, Version 2.0: User's Guide**. 2003. Gen. Tech. Rep. RMRS-XXX. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. XXX p.

Bradshaw, Larry S.; Deeming, John E.; Burgan, Robert E.; Cohen, Jack D., compilers. 1983. **The 1978 National Fire-Danger Rating System: Technical Documentation**. Gen. Tech. Rep. INT-169. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 144 p.

Bradshaw, L.; McCormick, E. 2000. **FireFamily Plus user's guide, version 2.0**. Gen. Tech. Rep. RMRS-GTR-67WWW. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Bradshaw, Larry S.; Fischer, William C., compilers. 1984. **Computer programs for summarizing climatic data stored in the National Fire Weather Data Library**. Gen. Tech. Rep. INT-164. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 39 p.

Burgan, Robert E. 1988. **Revisions to the 1978 National Fire-Danger Rating System.** Res. Pap. SE-273. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 39 p.

Cohen, E.; Nostrant, R.; Hawk, K.; Mitchell, W. 1994. **pcFIRDAT/pcSEASON User Guide: FireFamily for personal computers**. Sacramento, CA: State of California, California Department of Forestry and Fire Protection. 46 p.

Environmental Systems Research Institute, Inc. (ESRI). 2000. **ArcView 3.2a/Spatial Analyst**. Redlands, CA.

ERDAS 1999. **ERDAS IMAGINE 8.5**. Atlanta, Georgia.

Finney, Mark. A. 1998. **FARSITE: Fire Area Simulator--model development and evaluation**. Res. Pap. RMRS-RP-4. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 47 p.

Finney, Mark. A. 2000. **A spatial analysis of fire behavior associated with forest blowdown in the Boundary Waters Canoe Area, Minnesota**. Duluth, MN: U.S. Department of Agriculture, Superior National Forest. Available at: http://www.superiornationalforest.org/july4thstorm1999/bwcara/bwcawra.html.

Finney, Mark. A. 2001. **Design of regular landscape fuel treatment patterns for modifying fire growth and behavior**. Forest Science. 47: 219-228.

Finney, Mark. A. 2002. **Fire growth using minimum travel time methods**. Canadian Journal of Forest Research. 32: 1420-1424.

Finney, Mark. A. [In preparation]. **FlamMap**. Missoula, MT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory.

Frew, James E., Jr. 1990. **The Image Processing Workbench**. Santa Barbara, CA: University of California. 305 p. Dissertation.

Long, Donald G.; Ryan, Kevin C.; Stratton, Rick D. [In preparation]. **Southern Utah Fuel Management Demonstration Project.** Missoula, MT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. Available at: http://www.firelab.org/fep/research/sufm/home.htm.

Main, William A.; Paananen, Donna M.; Burgan, Robert E. 1990. **FIREFAMILY 1988**. Gen. Tech. Rep. NC-138. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station.

NOAA 2003. **Windspeed conversion chart**. Available at: http://www.seawfo.noaa.gov/fire/olm/fire/10togust.htm.

U.S. Department of Agriculture, Forest Service. 1993. **National Interagency Fire Management Integrated Database (NIFMID) reference manual**. Washington, DC: U.S. Department of Agriculture, Forest Service.

U.S. Department of Agriculture, Forest Service. 1996. **KCFAST: Kansas City Fire Access Software user's guide**. Washington, DC: U.S. Department of Agriculture, Forest Service, Fire and Aviation Management. Historical Fires Available at: http://famweb.nwcg.gov/kcfast/html/ocmenu.htm. Historical Weather Available at: http://famweb.nwcg.gov/kcfast/html/wxmenu.htm.

U.S. Department of Agriculture, Forest Service; U.S. Department of Interior. 2000. **A Report to the President: In Response to the Wildfires of 2000**. Washington, D.C.

U.S. Department of Interior, Bureau of Land Management. 2003. **Greenville Bench Enhancement Project, Environmental Assessment Report**. Cedar City Field Office, UT. 49 p.